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Exploring the role of multifunctional agriculture on the future of agriculture and rural development

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Abstract
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$35,000 for year one
$30,000 for year two

Q How can we implement multifunctional agriculture (MFA) in an Intense Managed Landscape? Is it even realistic and feasible? Which are the barriers for implementing MFA?

A This project made progress in identifying the barriers.

Background

High levels of soil organic matter (SOM) are critical for sustaining healthy soils; however, the collective effects of rainfall/runoff- and tillage-induced erosion can trigger enhanced soil and SOM losses. This study coupled a physically based erosion model (i.e., the Water Erosion Prediction Project model, WEPP) and a biogeochemical/ SOM dynamics model (i.e., CENTURY) to help explain the relationships between management practices and rainfall/ runoff- and tillage-induced erosion under historical, current, and hypothetical management scenarios. Better knowledge of SOM dynamics is critical for sustaining agricultural soils and assessing the overall health of a watershed.

The specific objectives of this study were to:

1. Develop a methodological framework that couples WEPP and CENTURY to quantify better SOM losses due to rainfall/runoff- and tillage-induced erosion, as well as decomposition.
2. Calibrate and verify the coupled models with collected field data and reported literature values.
3. Determine the long-term effects of land management and climate on SOM stocks in the Clear Creek (Iowa) watershed.
4. Gauge the status quo of SOM under current management practices and climate to ultimately determine the state of soil quality in Clear Creek.
5. Perform a cost-benefit analysis for current and alternative management practices used in Clear Creek.

Approach and methods

The research team calibrated and verified the coupled models using data from representative hillslopes in the Clear Creek watershed and projected the model results to the watershed scale for assessing the current soil quality in the watershed. Additionally, a cost-benefit analysis of current and alternative land management was conducted to determine a sound management strategy for agricultural watersheds.

Thanos Papanicolaou and Chris Wilson conduct outreach about the alternative tile installation.

Results and discussion

The coupled models captured the impact that historic land management practices and climatic conditions had on SOM for the representative hillslopes. The results from this study showed that for the first 60 years of cultivation, the representative hillslopes lost 57 percent of the available SOM in the active layer. However, there is a positive message regarding the state of SOM stocks. The current corn-soybean crop rotations are building SOM and increasing soil quality through the use of conservation practices, such as reduced tillage, which minimize SOM losses due to erosion. Proper row cropping practices can have a positive effect on SOM. What this study shows is that management practices do play a significant role in the road of recovery and sequestering SOM---what cannot be controlled are the climate and the markets.

The cost-benefit analysis and a soil quality-grading matrix evaluated the current and alternative management practices. Overall assessment of the practices showed that although the Conservation Reserve Program (CRP) provided the best soil quality for the landscape, it could not compete with the grain production revenue generated by the different cropping strategies. A balanced management practice that maintains high soil quality and is economically sound is spring-till corn – no-till soybean (STC-NTB). This rotation can build SOM stocks with only moderate losses due to erosion. Economically, the rotation features a balanced income from both corn and soybeans, and relatively low machinery costs due to no-till and reduced tillage operations. Obtaining an accurate assessment of the carbon fluxes associated with agricultural land management practices can provide more insight to global climate change and mitigation, help determine greenhouse gas emission standards, and encourage development of incentives for good land stewards.

Conclusions

A modeling framework developed in this study coupled the WEPP and CENTURY models to account for the effects of rainfall/runoff- and tillage-induced erosion, as well as decomposition, on SOM stocks in agricultural watersheds. The coupled models were calibrated using historical crop yield data and verified with measured SOM values.

The coupled models captured the impact that historic land management practices and climatic conditions had on SOM for a representative hillslope in the Clear Creek watershed. An extended initialization period was used to establish steady state conditions for the SOM in the representative field so that the effects of the management practices could be seen. When the native prairies were plowed under and converted to agriculture around 1930, SOM stocks decreased by 57 percent due to the combined effects of rainfall/runoff- and tillage-induced erosion. Further enhancing this loss of carbon from the hillslope was the exposure of SOM through aggregate breakdown by raindrop impacts or tillage that increased decomposition.

Despite this, there is a positive message regarding the current state of SOM stocks in the agricultural fields of Clear Creek. Current corn-soybean rotations are building SOM and increasing soil quality through the use of conservation practices, such as reduced tillage, which minimize SOM losses due to erosion. In fact, for the repre-

Installation of the tile pipe.

sentative hillslope, SOM values are expected to reach levels similar to prairie conditions within the next 16 years, provided conservation practices continue to be employed.

With the use of a geo-spatial platform, the coupled models assessed the current state of soil quality for the watershed using the Soil Conditioning Index. The results showed that all current management practices had positive SCI values, which means they are building SOM and improving soil quality.

A cost-benefit analysis using a net revenue assessment and a soil quality-grading matrix evaluated current and alternative management practices. The overall assessment of the practices showed that although CRP provided the best soil quality, it couldn't compete with the grain production revenue generated by the different cropping strategies. The strategies that favored increased corn production generated large amounts of SOM and yielded high income from corn grain markets/yields. However, several other existing negative impacts were not examined in this study, including decreased grain yields, increased fertilizer usage, and water quality degradation, as well as higher susceptibility to disease, weeds, and pests.

The STC-NTB rotation offers a balanced suite of management practices that maintain high soil quality and is economically sound. It is capable of building SOM stocks with only moderate losses due to erosion. Economically, the rotation produces a balanced income coming from both corn and soybeans, and relatively low machinery costs due to no-till and reduced tillage operations. For these reasons, the STC-NTB rotation should be considered seriously for possible management strategy plans for restoring soil quality.

Overall, this modeling framework worked well modeling SOM stocks. It will allow researchers to simulate a wide range of management strategies to project performance in five or even 25 years, since the response time of SOM to different practices can be lengthy.

Impact of results

In addition to providing accurate estimates of SOM under a variety of management practices, the coupled models could be used to assess additional services that agroecosystems provide. Multifunctional Agriculture (MFA) focuses on ecosystem services in addition to food production. These services include carbon sequestration, decreased CO_2 emissions, improved water quality, and biodiversity to promote environmental rehabilitation and landscape sustainability.

Many MFA concepts have been applied to minimal agricultural producing countries and developing nations, but to incorporate these concepts within intensively managed agricultural systems requires a solid modeling framework that offers reliable estimates of the services to stakeholders.

The modeling framework established here can provide more detailed carbon budgets by accounting for losses associated with increased erosion and respiration due to rainfall/runoff and tillage. The carbon budgets then can be used to establish payment incentives based on varying levels of conservation practice implementation. Further, water quality could be assessed using runoff volume and sediment delivery ratios to provide fluxes of material entering channel networks.

Having coupled models that can simulate a wide range of management practices and provide accurate estimates of ecosystem services will facilitate implementation of MFA. This modeling framework can be used to convey information among the many stakeholders present at local and regional levels, empower farmers and reward good land stewardship.

Education and outreach

The project sponsored an interactive exhibit at the 2011 Iowa State Fair. Visitors to the exhibit conducted simple experiments with an in-situ gas chamber to measure CO_2 emissions from different pots of soil that represented tilled soil, no-till soil, and soil mixed with corn residue. The experiments were designed to improve the visitors' understanding of carbon cycle science, and help them see how these types of measurements provide important carbon management knowledge for farmers and policy decision makers, especially in the agricultural regions of the Midwest.

In addition, the project was featured in the Leopold Center "On the Ground" video series. The video shoot showcased faculty and students working on the project, who spoke about the different components of the ongoing research. The video is on the Leopold Center website (http://www.leopold.iastate.edu/news/on-the-ground/carbon-movement-Iowa-landscapes).

Project investigators reported on their work at conferences in San Francisco, California; Brisbane, Australia; Minneapolis, Minnesota; Urbana-Champaign, Illinois; and Iowa City. They submitted additional proposals drawing on this work to six foundations for possible future funding.

Leveraged funds

No additional funds were leveraged by this project.

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